



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
19.12.2018 Bulletin 2018/51

(51) Int Cl.:
A61L 26/00 (2006.01)

(21) Application number: **18177873.9**

(22) Date of filing: **15.06.2010**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR

- **DOBBYN, Peter**
Co Cork (IE)
- **O'DONOGHUE, John**
Co Waterford (IE)
- **O'NEILL, Liam**
Co Cork (IE)

(30) Priority: **16.06.2009 US 18734009 P**

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
10789079.0 / 2 442 833

(74) Representative: **Pitchford, James Edward et al**
Mathys & Squire LLP
The Shard
32 London Bridge Street
London SE1 9SG (GB)

(71) Applicant: **TheraDep Technologies, Inc.**
Palo Alto, CA 94306 (US)

Remarks:

This application was filed on 14-06-2018 as a divisional application to the application mentioned under INID code 62.

(72) Inventors:
• **O'KEEFFE, Joe**
Co Cork (IE)

(54) **WOUND HEALING DEVICE**

(57) A plasma coating device for treating a wound comprises a plasma chamber having: one or more electrodes, a gas supply inlet, a plasma outlet exposed to ambient pressure, and an ignition system operatively connected to the electrodes for providing a non-thermal

equilibrium plasma within the plasma chamber. An aerosol delivery system is operable to introduce a bioresorbable material as an aerosol into the plasma, to produce a coating on the wound surface.

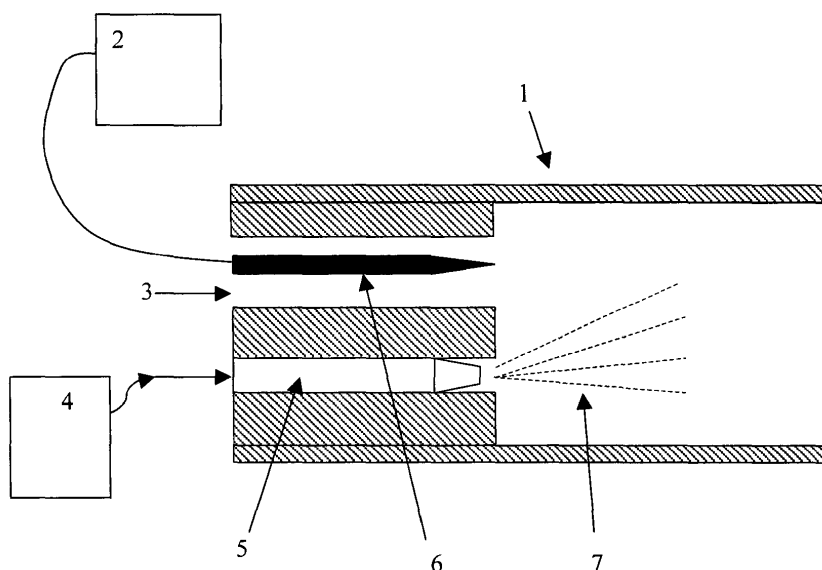


Figure 1

Description

Background

[0001] Electrical plasma devices are well established in medicine. For example, Massarweh et al, J. Am. Coll. Surg., 2006, 202 (3), 520, discloses plasma devices for surgery; Reich et al, European Urology, 2003, 44 (2), 272-276, describe the use of an argon plasma (APC) to coagulate blood and stop bleeding; and Mennel et al, Experimental and Toxicological Pathology, 2002, 54 (3), 255, disclose using a helium plasma to obtain a similar response to the APC technique.

[0002] Plasmas can also be used to sterilise skin as disclosed in G. Fridman, A.D. Brooks, M. Balasubramanian, A. Fridman, A. Gustol, V.N. Vasilets, H. Ayan, G. Friedman, Plasma Process. Polym. 4 (2007) 370 and WO2006/116252. The use of plasma devices to promote wound healing has also been disclosed in US2008/0237484 and in WO2009/101143.

[0003] Outside of medicine, plasma devices are widely used to produce thin film coatings in industrial applications. Plasma polymers offer a number of advantages over conventional polymer coatings. The combination of reactive plasma and chemically active monomers produces a coating that is uniform, pin hole free and well bonded to the substrate. Furthermore, the curing can occur in a manner that is almost instantaneous, offering numerous processing advantages.

[0004] US 4,929,319 describes a method for depositing a polymer coating in which an aerosol is introduced into a corona plasma and the reactive species thereby generated are allowed to deposit in a substrate that is also brought into the corona plasma.

[0005] WO 02/28548 describes a process in which an aerosol is introduced into an atmospheric pressure glow discharge (APGD) plasma and a coating is thereby formed on a substrate. The coating chemistry was found to be virtually unchanged from that of the precursor molecules by the exposure to the homogeneous APGD plasma.

[0006] WO2005/106477 describes a process for coating a substrate with a biomolecule in which the substrate is placed between two electrodes and a plasma is generated by applying an alternating current in which a positive voltage is applied to the first electrode and a zero voltage to the second electrode, and then a zero voltage to the first electrode and a negative voltage to the second electrode. A coating is then applied by introducing a reactive precursor to form a coating and biomolecules are simultaneously immobilised. The biomolecules may be introduced as an aerosol.

[0007] WO 05/110626 discloses coating a substrate with a polymer layer containing active agents. The method involves exposing a mixture of polymer forming materials (which react to form chemical bonds in a plasma) and active agents (which do significantly react in the plasma) to plasma. The polymer forming materials listed in-

clude various acrylates, alkenes and dienes that can be polymerised by the reactive species present within a plasma.

[0008] These prior documents rely on the plasma to induce the polymerisation of a monomer to produce the thin film or coating. The polymerisation can be driven through free radical (A. Bogaerts et al., Spectrochimica Acta Part B, 57 (2002) 609-658) or cationic reaction mechanisms (Daniel C. Guerin, David D. Hinshelwood, Sorin Monolache, Ferencz S. Denes, and Vasgen A. Shamamian, Langmuir, 2002, 18 (10), pp 4118-4123).

[0009] Thus, while the methods described in WO 05/106477 and WO 05/110626 do allow for the deposition of polymers containing active agents, they are reliant upon the presence of a precursor which can react in the plasma to form the polymer coating during the deposition process. The requirement to induce reactions within the polymer precursor without damaging the active agent limits the degree of polymerisation that can be achieved.

Summary of the Invention

[0010] The present invention provides a plasma device as claimed in claim 1.

[0011] In a further aspect, there is provided a non-thermal plasma treated bioresorbable material for use in coating a wound as claimed in claim 14.

[0012] In a still further aspect there is provided a method of treating a wound according to claim 22.

[0013] In embodiments of the present invention, a non-thermal plasma is applied to a wound. The plasma can sterilise the area, coagulate blood and deposit a bioresorbable coating to seal the wound area. The coating can further include active compounds to aid in wound healing.

[0014] The bioresorbable material can include blood plasma, chitosan or collagen, but may alternatively or in addition include a protein, a biopolymer (such as chitin, alginates, cellulose or hyaluronan), or a synthetic biodegradable polymer (such as poly (lactic-co-glycolic acid) (PLGA), polylactic acid, polycaprolactone, polyglactin) or a mixture of such materials.

[0015] Preferably, the bioresorbable material is introduced into a non-thermal plasma as a precursor in the form of an aerosol. The bioresorbable material precursor can either be dissolved or dispersed in a suitable carrier liquid.

[0016] Preferably, the active compound, for example, drug, enzyme, cell, protein or DNA may be either introduced into the plasma dissolved in the bioresorbable material precursor or introduced separately.

[0017] In such implementations, the active compound is incorporated alongside a prepolymerised polymer which allows the polymerisation and film forming steps to be separated out and provides a greater degree of process control.

[0018] The mixture of bioresorbable material, active compound and plasma further interact to produce a coat-

ing on the wound surface. The wound can either directly contact the plasma or can be placed downstream of the plasma chamber outlet.

[0019] In one embodiment, blood constituents are nebulised into the plasma, to deposit a layer of coagulated blood or blood plasma onto a wound surface.

Brief Description of the Drawings

[0020] Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawing, in which:

Figure 1 is a schematic view of a plasma device in accordance with an embodiment of the present invention.

Description of the Preferred Embodiments

[0021] Referring now to Figure 1, there is shown a schematic view of a plasma device according to an embodiment of the invention. The device includes a plasma chamber 1 including a metal electrode 6 to which a high voltage power supply / ignition system 2 is operatively connected. The chamber 1 further includes a gas inlet port 3 through which a supply of gas, for example, helium, argon or nitrogen or mixtures thereof is fed in operation of the device and which in combination with the ignition system causes a plasma to be struck and to stream from an outlet 8 of the plasma chamber. In the illustrated embodiment, a liquid delivery system 4 is operatively connected to an inlet of the plasma chamber and an internal nebuliser 5 causes the supplied liquid to be sprayed into the chamber 1 as an aerosol. In alternative embodiments, not shown, an external nebuliser feeds the aerosol to a region outside the plasma chamber where it interacts with the reactive species emanating from the outlet 8 of the plasma chamber before coating a wound over which the plasma device is being passed.

[0022] In embodiments of the present invention, the plasma device initially sterilises and coagulates the wound. Then, by providing an aerosol from the supply 4 containing a bioresorbable material which may also contain an active agent, and introducing that aerosol into a plasma chamber 1, or into the reactive species that exist downstream of the plasma chamber 1, the device produces a coating on the wound. If required, the sterilisation, coagulation and coating deposition can occur simultaneously. Deposition of such a coating enables the continuous interaction of the pro-healing materials with the wound and provides for enhanced wound healing. Furthermore, the coating seals the wound and limits the opportunity for further bacteria to infect the wound site.

[0023] The term wound can be taken to encompass all forms of damage to the skin or body including burns, cuts, tears, piercings, contusions, abrasions, lacerations, punctures, gun shots or other forms of injury to the body. It may also encompass infections or chronic wounds such as ulcers.

[0024] The invention described herein allows the intro-

duction of bioresorbable material including: proteins such as collagen, fibrin or fibronectin; biopolymers such as hyaluronan, chitosan, alginates and cellulose; and also biodegradable synthetic polymers such as PLGA which do not form using the same vinyl polymerisation reactions favoured by conventional plasma reactions onto a wound site. The plasma may cross-link these materials to produce a dry coating, but the degree of cross-linking is limited and is not sufficient to alter the functionality of the deposited material.

[0025] Embodiments of the present invention employ non-thermal plasma devices where the plasma operates close to room temperature thus allowing the processing of temperature sensitive materials, without imposing a damaging thermal burden onto the material. Nonetheless, the hot electrons of the plasma create, through high-energy collisions, a rich source of radicals and excited species with a high chemical potential energy capable of chemical and physical reactivity. Non-thermal equilibrium plasmas can be created at ambient pressure and have been reviewed extensively by Roth (Roth J.R., Industrial Plasma Engineering, Volume 2 Applications to Non-thermal Plasma Processing, Institute of Physics Publishing, 2001, pages 37-73). Such plasmas include dielectric barrier discharges. Another non-thermal equilibrium plasma is the Atmospheric pressure glow discharge (APGD) as described by Okazaki et al (J. Phys. D: Appl. Phys., 26, 889-892 (1993)). These APGD plasmas have been described extensively by Roth as One Atmosphere Uniform Glow Discharge Plasmas (OUAGDP) and are found to operate from 0.5 to 40 kHz. Corona plasma devices can also operate in non-thermal equilibrium mode. Various plasma jets are also capable of operating in a "cold" or non-thermal equilibrium mode.

[0026] Embodiments of the present invention employ plasma devices operating at frequencies above 100 kHz, which is beyond the sensory threshold of a patient's nervous system. For optimum control, the plasma is operated below 500 kHz and may be pulsed on and off in a controlled fashion to minimise the energy delivered to the aerosol and patient. This enables controlled plasma reactions that preserve precursor functionality and do not damage or fragment sensitive active species.

[0027] Alternatively, the plasma can be contained between two electrodes, with a grounded electrode separating the person or object to be treated from the plasma, such that no significant voltage is applied to any object or person placed downstream of the device. This can be accomplished using a plasma device such as described by Ladwig et al (Surface & Coatings Technology 201 (2007) 6460-6464). Use of such a plasma device would allow the plasma to operate at frequencies below 100 kHz.

[0028] The plasma parameters (electrode design, frequency, voltage, gas composition, etc.) can be chosen to control the plasma process and ensure that the plasma operates in a non-thermal manner to produce a low-temperature plasma, which does not adversely affect tem-

perature sensitive materials which are being deposited.

[0029] Furthermore, the precursor can be introduced downstream of the plasma chamber outlet to minimise damage to the coating forming materials. This allows coatings containing materials sensitive to temperature, ions, free radicals and other active species present in the plasma to be deposited where they would otherwise be damaged if introduced directly into the plasma chamber.

[0030] Various active compounds can be incorporated into the coating produced by this device. These can include anti-cancer drugs, anti-inflammatory drugs, immuno-suppressants, antibiotics, antimicrobials, heparin, a functional protein, a regulatory protein, structural proteins, oligo-peptides, antigenic peptides, nucleic acids, immunogens, glycosaminoglycans and combinations thereof.

[0031] Other active compounds include polypeptides, polyglycans, hormones, lipids, interferons, cartilage, therapeutic biologic agents both cellular and synthetically derived, autologous, homologous and allographic and xenographic biologic agents, autologous or homologous, recombinant and synthetic derived blood cells and products containing antimicrobial/antibiotic agents, bacteriostatic agents, stem cells, stromal cells; fibroblast derived Human Dermal Collagen, matrix proteins, growth factors and cytokines, fibronectin, cells found in loose connective tissue such as endothelial cells, cells found in adipose tissue, macrophages/monocytes, adipocytes, pericytes, reticular cells found in bone marrow stroma and cultured autologous keratinocytes.

[0032] In a preferred application, the wound is coated with a layer of either coagulated blood or blood extracts. The coating is produced by nebulising a supply of blood, or blood constituents, into the plasma chamber or into the species exiting from the plasma chamber. This offers a route to producing thin films, which are highly biocompatible and already contain the necessary factors (fibrin, cytokines, etc.) necessary to seal the wound and to induce wound healing.

[0033] Nonetheless, the nature of the deposited layer may be varied dependent on factors including: the underlying cause of the wound, the characteristics of the wound, the stage of wound healing, the particular patient needs and risk factors, availability of autologous materials.

[0034] Thus, different depositions can be used depending on whether wound healing is at the haemostasis, inflammation, proliferation/granulation or maturation/remodelling phase. Examples of materials for the various phases of wound healing include:

1. Fresh trauma/burns: Seal/contain wound with a temporary resorbable material containing appropriate active agents including, for example, antimicrobials, analgesics, vasoconstrictors in order to contain the wound while minimising dehydration/shock, pain, blood loss, risk of infection/contamination, further tissue loss, etc and initiating haemostasis.

2. Haemostasis stage: A resorbable material such as blood plasma or platelets including active agent(s) such as, vasoconstrictors, adenosine diphosphate (ADP), thrombin, fibrinogen/fibrin, cytokines (PDGF), chemotactic factors, chemocines or coagulation factors.

3. Inflammation stage: A resorbable material such as blood plasma including, for example, neutrophils, monocytes, phagocytes, mast cells, proteolytic enzymes, leukocytes.

4. Proliferation/granulation stage: A resorbable material including for:

- a. Granulation - macrophages, Fibroblastic Growth Factor (FGF), Epidermal Growth Factor (EGF), transforming growth factor beta (TGF-beta), Extra cellular matrix (ECM), fibroblasts, myofibroblasts
- b. Contracture - fibroblasts, collagen, endothelial cells, keratinocytes, angiocytes, neurocytes,
- c. Epithelisation - growth factors, fibrin, collagen, and fibronectin

5. Maturation/remodelling: Type I collagen.

6. Enhanced/accelerated wound healing or for large wound and burn injuries or chronic non-healing ulcers: Cytokines and growth factors

[0035] Other applications including cornea regeneration using cytokines following abrasion or cataract treatment.

[0036] All variants may also provide the following:

- A moisture retaining occlusive barrier and high humidity at the wound surface;
- Gaseous exchange;
- Thermal insulation; and
- Protection against secondary infection

Examples:

1. Deposition of blood plasma coating

[0037] A biocompatible coating was deposited on to a glass slide using a non-thermal plasma discharge and blood plasma as the precursor. The plasma discharge was created by applying an alternating voltage to a corona needle electrode assembly within a dielectric housing. The voltage was applied at a frequency of 100 kHz from a Redline G2000 high voltage power supply. Helium was used as a ballast gas at a flow rate of 14 litres/minute. (It will be appreciated that other gases including argon or nitrogen or mixtures thereof could also be used.) The blood plasma extract was nebulised into the plasma using a Burgener pneumatic nebuliser (Burgener Research, Canada) at a flow rate of 51 microlitres/min. The input power was applied using a 45% duty cycle (ratio of time on to time off) and a selected input power on the

power supply of 107 V. This corresponded to an actual applied voltage of 12.7 kV (pk-pk) applied to the electrodes. The substrate was a glass slide placed approximately 5 mm downstream of the plasma exit.

[0038] The blood plasma was sprayed through the plasma and landed upon the glass slide, where it coagulated instantly to form a coating. After deposition, the coating was inspected at a magnification of 40X and the viable cell numbers were counted. Prior to being exposed to the electrical discharge, cell viability was estimated to be 90%. After undergoing nebulisation and plasma coagulation, over 70% of the cells were still deemed viable, indicating that biological materials have been successfully deposited intact and capable of participating in a biological healing process.

2. Deposition of a biopolymer (chitosan)

[0039] Chitosan is known to have antimicrobial properties and is also a common scaffold material used in regenerative medicine. Water-soluble chitosan was dissolved in deionised water to give a concentration of 20 mg/ml. This liquid was introduced at 50 μ L/min into the equipment described in Example 1 and coatings were deposited onto glass slides. Coatings were deposited at a power input setting of 170V and 150 kHz and for times of 45 seconds, 1 minute and 3 minutes. In each case, a clear coating was detected on the surface of the glass slide. This coating was not removed by wiping with a tissue, indicating that the coating was dry, cured and adherent.

3. Deposition of a protein solution (collagen) at low frequency

[0040] Collagen is a known aid in wound healing process and is a key component of skin. A plasma device comprising a needle corona electrode powered by a 100W Plasma Technics Inc power supply operating at c. 20 kHz was provided. Helium was introduced to the system at a rate of 8 litres/minute. An acidified solution of collagen (3.8 mg/ml) was nebulised into the resultant discharge at a flow rate of 50 μ L/min and coatings were deposited onto glass slides for 1 - 2 minutes. All deposits were found to be coherent, dry and adhered well to the substrate, indicating that a cured coating had been formed.

4. Deposition of a protein solution (collagen) at high frequency

[0041] A solution of collagen (1 mg/ml) was introduced into the equipment described in Example 1. The plasma was operated at 115V input power, 148 kHz and a duty cycle of 44%. Helium was introduced at a rate of 5 litres/min. The collagen solution was introduced at a rate of 50 μ L/min and a coating was deposited onto polished Si wafers for either one minute or two minutes. Ellipsom-

etry detected a coating with a thickness of 50 nm for the one minute sample and 140 nm for the two minute sample, confirming that a coating had been deposited.

[0042] Aspects and features of the present disclosure are set out in the following numbered clauses which contain the subject-matter of the claims of the parent European patent application as originally filed:

1. A plasma coating device for treating a wound comprising a plasma chamber having: one or more electrodes, a gas supply inlet, a plasma outlet exposed to ambient pressure, and a ignition system operatively connected to said electrodes for providing a non-thermal equilibrium plasma within the plasma chamber; and an aerosol delivery system operable to introduce a bioresorbable material as an aerosol into the plasma, to produce a coating on the wound surface.
2. A plasma coating device according to clause 1 in which said aerosol delivery system is arranged to provide said aerosol into the plasma chamber.
3. A plasma coating device according to clause 1 in which said aerosol delivery system is arranged to provide said aerosol into a region containing reactive species emanating from said plasma chamber outlet.
4. A plasma coating device in which said aerosol delivery system is arranged to contain a bioresorbable material pre-cursor either dissolved or dispersed in a carrier liquid.
5. A plasma coating device according to clause 1 wherein said ignition system is arranged to provide power to said plasma at a frequency of at least 100kHz.
6. A plasma coating device according to clause 1 wherein said ignition system is arranged to provide power to said plasma at a frequency of between 100kHz and 500kHz.
7. A plasma coating device according to clause 1 wherein said ignition system is arranged to pulse said plasma.
8. A plasma coating device according to clause 1 further comprising a ground electrode disposed between the plasma chamber outlet and the wound to be treated.
9. A plasma coating device according to clause 1 wherein the plasma is one of a dielectric barrier discharge; an atmospheric pressure glow discharge, a corona plasma or a plasma jet.
10. A plasma coating device according to clause 1 wherein said aerosol delivery system is arranged to supply said aerosol to said wound after a period of treating the wound with only said plasma.
11. A plasma coating device according to clause 1 further comprising means for providing an active compound to said wound in conjunction with said plasma treated bioresorbable material.
12. A plasma coating device according to clause 11

wherein said active compound is either dissolved in the bioresorbable material pre-cursor or introduced separately to the plasma

13. A plasma coating device according to clause 1 further comprising a gas supply arranged to provide a supply of helium, argon, nitrogen or mixtures thereof to said chamber.

14. A non-thermal equilibrium plasma treated bioresorbable material for use in coating a wound.

15. A material for use in coating a wound according to clause 14 wherein the bioresorbable material is a biopolymer, a biodegradable polymer, a protein or a mixture thereof.

16. A material for use in coating a wound according to clause 15 comprising a protein including collagen, fibrin or fibronectin; a biopolymer including chitin, hyaluronan, chitosan, alginates or cellulose; or a biodegradable polymer including PLGA, polylactic acid, polycaprolactone or polyglactin.

17. A material for use in coating a wound according to clause 14 comprising one of: blood, blood plasma or a blood constituent.

18. A material for use in coating a wound according to clause 14 further comprising one of a pharmaceutical agent or a biologically active compound or combinations thereof.

19. A material for use in coating a wound according to clause 18 comprising one or more of a drug, enzyme, cell, protein or DNA.

20. A material for use in coating a wound according to clause 14 further including one or more of anti-cancer drugs, anti-inflammatory drugs, immunosuppressants, antibiotics, antimicrobials, heparin, a functional protein, a regulatory protein, structural proteins, oligo-peptides, antigenic peptides, nucleic acids, immunogens, glycosaminoglycans.

21. A material for use in coating a wound according to clause 14 further including one or more of polypeptides, polyglycans, hormones, lipids, interferons, cartilage, therapeutic biologic agents both cellular and synthetically derived, autologous, homologous and allographic and xenographic biologic agents, autologous or homologous, recombinant and synthetic derived blood cells and products containing antimicrobial or antibiotic agents, bacteriostatic agents, stem cells, stromal cells; fibroblast derived Human Dermal Collagen, matrix proteins, growth factors and cytokines, fibronectin, cells found in loose connective tissue such as endothelial cells, cells found in adipose tissue, macrophages, monocytes, adipocytes, pericytes, reticular cells found in bone marrow stroma or cultured autologous keratinocytes.

22. A method of treating a wound comprising: providing a plasma coating device according to clause 1 and applying a non-thermal equilibrium plasma treated bioresorbable material to coat the wound.

23. A method according to clause 22 wherein the

wound comprises a fresh trauma or a burn and wherein the bioresorbable material contains one or more of an antimicrobial compound, an analgesic or vasoconstrictors.

24. A method according to clause 22 wherein the wound is at a haemostasis stage and wherein said bioresorbable material comprises either blood plasma or platelets including one or more of vasoconstrictors, adenosine diphosphate, thrombin, fibrinogen, fibrin, cytokines, chemotactic factors, chemokines or coagulation factors.

25. A method according to clause 22 wherein the wound is at an inflammation stage and wherein said bioresorbable material comprises blood plasma including one or more of neutrophils, monocytes, phagocytes, mast cells, proteolytic enzymes or leukocytes.

26. A method according to clause 22 wherein the wound is at a granulation stage and wherein said bioresorbable material includes one or more of macrophages, Fibroblastic Growth Factor, Epidermal Growth Factor, transforming growth factor beta, extra cellular matrix, fibroblasts or myofibroblasts.

27. A method according to clause 22 wherein the wound is at a contracture stage and wherein said bioresorbable material includes one or more of fibroblasts, collagen, endothelial cells, keratinocytes, angiocytes or neurocytes.

28. A method according to clause 22 wherein the wound is at an epithelisation stage and wherein said bioresorbable material includes one or more of growth factors, fibrin, collagen or fibronectin.

29. A method according to clause 22 comprising remodelling a wound and wherein said bioresorbable material comprises type I collagen.

30. A method according to clause 22 comprising treating a large wound, burn injury or chronic non-healing ulcer and wherein said bioresorbable material comprises cytokines and growth factors.

31. A method according to clause 22 comprising regenerating a cornea and wherein said bioresorbable material comprises cytokines.

Claims

1. A wound coating material comprising a non-thermal equilibrium plasma-treated bioresorbable material that is at least partially cross-linked, and wherein the plasma-treated bioresorbable material is pharmaceutically-active, biologically-active, or a combination thereof.

2. The wound coating material of claim 1, wherein the plasma-treated bioresorbable material comprises a biopolymer, a biodegradable polymer, a protein, or a mixture thereof.

3. The wound coating material of claim 2, wherein the plasma-treated bioresorbable material comprises a protein selected from collagen, fibrin, and fibronec-
tin.
4. The wound coating material of claim 2, wherein the plasma-treated bioresorbable material comprises a biopolymer selected from chitin, hyaluronan, chi-
tosan, alginate, and cellulose.
5. The wound coating material of claim 2, wherein the plasma-treated bioresorbable material comprises a biodegradable polymer selected from poly(lactic-co-
glycolic acid), polylactic acid, polycaprolactone, and polyglactin.
6. The wound coating material of claim 1, wherein the plasma-treated bioresorbable material comprises blood, blood plasma, or a blood constituent.
7. The wound coating material of claim 1, wherein the plasma-treated bioresorbable material comprises a pharmaceutical agent, a biologically-active com-
pound, or combinations thereof.
8. The wound coating material of claim 7, wherein the plasma-treated bioresorbable material comprises one or more biologically-active compounds selected
from an enzyme, a protein, and DNA.
9. The wound coating material of claim 7, wherein the plasma-treated bioresorbable material comprises one or more pharmaceutically-active or biologically-
active compounds selected from an anticancer drug, an anti-inflammatory drug, an immuno-suppressant, an antibiotic, an antimicrobial, heparin, a functional
protein, a regulatory protein, a structural protein, an oligo-peptide, an antigenic peptide, a nucleic acid, an immunogen, a glycosaminoglycan, a polypeptide,
a polyglycan, a hormone, a lipid, interferon, cartilage, a therapeutic biologic agent, an autologous biologic agent, a homologous biologic agent, an allogenic bi-
ologic agent, a xenogenic biologic agent, a bacteri-
ostatic agent, a fibroblast derived Human Dermal
Collagen, matrix proteins, a growth factor, cytokines,
and fibronectin.
10. The wound coating material of claim 1, wherein the plasma-treated bioresorbable material comprises one or more cells selected from an autologous blood
cell, a homologous blood cell, a stem cell, a stromal
cell, cells found in adipose tissue, a macrophage, a
monocyte, an adipocyte, a pericyte, reticular cells
found in bone marrow stroma, a cultured autologous
keratinocyte, and a combination thereof.
11. A wound coating material comprising a non-thermal
equilibrium plasma-treated collagen, wherein the
plasma-treated collagen is at least partially cross-
linked, and wherein the plasma-treated collagen is
biologically-active in order to aid in wound healing.
12. The wound coating material of claim 11, further com-
prising a pharmaceutical agent, a biologically-active
compound other than collagen, or combinations
thereof.
13. The wound coating material of claim 12, wherein the
wound coating material comprises one or more bio-
logically-active compounds selected from an en-
zyme, a protein, and DNA.
14. The wound coating material of claim 12, wherein the
wound coating material comprises one or more phar-
maceutically-active or biologically-active com-
pounds selected from an anticancer drug, an anti-
inflammatory drug, an immuno-suppressant, an an-
tibiotic, an antimicrobial, heparin, a functional pro-
tein, a regulatory protein, a structural protein, an ol-
igo-peptide, an antigenic peptide, a nucleic acid, an
immunogen, a glycosaminoglycan, a polypeptide, a
polyglycan, a hormone, a lipid, interferon, cartilage,
a therapeutic biologic agent, an autologous biologic
agent, a homologous biologic agent, an allogenic bi-
ologic agent, a xenogenic biologic agent, products
containing antimicrobial or antibiotic agents, a bac-
teriostatic agent, a fibroblast derived Human Dermal
Collagen, matrix proteins, a growth factor, cytokines,
and fibronectin.
15. The wound coating material of claim 11, further com-
prising one or more cells selected from an autolo-
gous blood cell, a homologous blood cell, a stem
cell, a stromal cell, cells found in adipose tissue, a
macrophage, a monocyte, an adipocyte, a pericyte,
reticular cells found in bone marrow stroma, a cul-
tured autologous keratinocyte, and a combination
thereof.

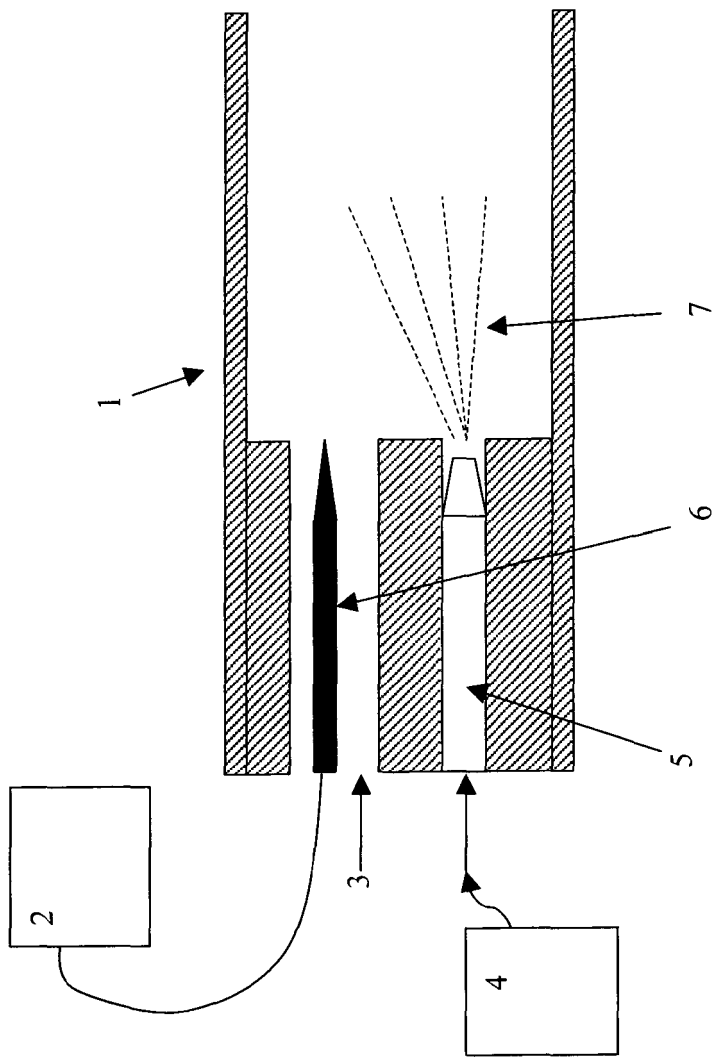


Figure 1



EUROPEAN SEARCH REPORT

Application Number
EP 18 17 7873

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2003/087985 A1 (HUBBELL JEFFREY A [US] ET AL) 8 May 2003 (2003-05-08) * page 3, paragraph 32-42 * * page 6, paragraph 101-102 * * page 7, paragraph 108 - page 9, paragraph 132 * * claims; examples 23-27 *	1-5,7-15	INV. A61L26/00
X	WO 89/01790 A1 (BIOCOMPATIBLES LTD [GB]) 9 March 1989 (1989-03-09) * page 2, line 7 - page 3, line 16 * * page 4, lines 18-23 * * claims *	1,2,4,7,9	
X	EP 1 498 128 A1 (NETECH INC [JP]) 19 January 2005 (2005-01-19) * page 3, paragraph 9-13 * * page 10, paragraph 50 - page 11, paragraph 54 * * claims *	1,2,4,7,9	
A,D	WO 2005/110626 A2 (DOW CORNING IRELAND LTD [IE]; GOODWIN ANDREW JAMES [IE]; LEADLEY STUAR) 24 November 2005 (2005-11-24) * page 2, paragraph 7 * * page 3, paragraph 9-10 * * page 8, paragraph 24-26 * * page 20, paragraph 49 - page 21, paragraph 53 * * claims *	1-15	TECHNICAL FIELDS SEARCHED (IPC) A61L
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 6 November 2018	Examiner Van den Bulcke, H
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 18 17 7873

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

06-11-2018

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003087985 A1	08-05-2003	NONE	
WO 8901790 A1	09-03-1989	EP 0381680 A1 JP H03500170 A WO 8901790 A1	16-08-1990 17-01-1991 09-03-1989
EP 1498128 A1	19-01-2005	AU 2003227447 A1 CA 2484453 A1 EP 1498128 A1 JP WO2003090765 A1 US 2005238702 A1 WO 03090765 A1	10-11-2003 06-11-2003 19-01-2005 25-08-2005 27-10-2005 06-11-2003
WO 2005110626 A2	24-11-2005	AU 2005243861 A1 CN 1953822 A EA 200602116 A1 EP 1744836 A2 JP 2008501069 A JP 2014132111 A KR 20070022265 A NZ 551697 A US 2008118734 A1 WO 2005110626 A2	24-11-2005 25-04-2007 27-04-2007 24-01-2007 17-01-2008 17-07-2014 26-02-2007 30-04-2010 22-05-2008 24-11-2005

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2006116252 A [0002]
- US 20080237484 A [0002]
- WO 2009101143 A [0002]
- US 4929319 A [0004]
- WO 0228548 A [0005]
- WO 2005106477 A [0006]
- WO 05110626 A [0007] [0009]
- WO 05106477 A [0009]

Non-patent literature cited in the description

- **MASSARWEH et al.** *J. Am. Coll. Surg.*, 2006, vol. 202 (3), 520 [0001]
- **REICH et al.** *European Urology*, 2003, vol. 44 (2), 272-276 [0001]
- **MENNEL et al.** *Experimental and Toxicological Pathology*, 2002, vol. 54 (3), 255 [0001]
- **G. FRIDMAN ; A.D. BROOKS ; M. BALASUBRAMANIAN ; A. FRIDMAN ; A. GUSTOL ; V.N. VASILETS ; H. AYAN ; G. FRIEDMAN.** *Plasma Process. Polym.*, 2007, vol. 4, 370 [0002]
- **A. BOGAERTS et al.** *Spectrochimica Acta Part B*, 2002, vol. 57, 609-658 [0008]
- **DANIEL C. GUERIN ; DAVID D. HINSELWOOD ; SORIN MONOLACHE ; FERENCZ S. DENES ; VASGEN A. SHAMAMIAN.** *Langmuir*, 2002, vol. 18 (10), 4118-4123 [0008]
- Industrial Plasma Engineering. **ROTH J.R.** Applications to Non-thermal Plasma Processing. Institute of Physics Publishing, 2001, vol. 2, 37-73 [0025]
- **OKAZAKI et al.** *J. Phys. D: Appl. Phys.*, 1993, vol. 26, 889-892 [0025]
- **LADWIG et al.** *Surface & Coatings Technology*, 2007, vol. 201, 6460-6464 [0027]